

CLAIMS

1. ~~In an optical communication system, apparatus for amplifying an optical signal,~~
5 said apparatus comprising:

a fiber; and

an optical pump energy source disposed to inject optical pump energy into said fiber in a co-propagating direction relative to a transmission direction of an optical signal in said fiber to cause Raman amplification of said signal in accordance with a gain level;

10 and

~~wherein said gain level is greater than 4 dB.~~

2. ~~The apparatus of claim 1 wherein either 1) given a signal-to-noise ratio, there is a greater four-wave mixing product suppression level than would be achieved using only a counter-propagating optical pump energy source to obtain said gain level or 2) given a four-wave mixing product suppression level, there is a higher signal to noise ratio than would be achieved using only said counter-propagating energy source to obtain said gain level.~~

20 3. In an optical communication system, apparatus for amplifying an optical signal, said apparatus comprising:

~~a first optical pump energy source disposed to inject optical pump energy into a~~
fiber in a co-propagating direction relative to a transmission direction of said optical
signal to cause Raman amplification of said signal in accordance with a first gain level;

5 a second optical pump energy source disposed to inject optical pump energy into
said fiber in a counter-propagating direction relative to said transmission direction of said
optical signal to cause Raman amplification of said signal in accordance with a second
gain level, said optical signal experiencing a total gain level including said first gain level
and said second gain level; and

10 wherein said first gain level is greater than 4 dB.

4. ~~The apparatus of claim 3 wherein either 1) given a signal to noise ratio, there is a~~
greater four-wave mixing product suppression level than would be achieved using only
said second optical pump energy source to obtain said total gain level or 2) given a four-
15 wave mixing product suppression level, there is a higher signal to noise ratio than would
be achieved using only said second optical pump energy source to obtain said total gain
level.

5. The apparatus of claim 3 wherein said first gain level is set responsive to a
20 minimum tolerable four-wave mixing product suppression level and a desired signal to
~~noise ratio.~~

6. The apparatus of claim 5 wherein said first gain level is also set responsive to a
maximum tolerable saturation level.

7. The apparatus of claim 5 wherein said second gain level is set responsive to said first gain level and said total gain level.

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8. ~~The apparatus of claim 3 wherein said first gain level and said second gain level are set responsive to a desired maximum double Rayleigh backscattering level.~~

9. ~~The apparatus of claim 3 wherein a power level of said first optical pump energy source is set responsive to said first gain level.~~

10. The apparatus of claim 3 wherein a power level of said second optical pump energy source is set responsive to said second gain level.

11. The apparatus of claim 3 further comprising said fiber.

12. The apparatus of claim 3 further comprising:

~~an Erbium doped fiber amplifier in cascade with said fiber.~~

13. ~~In an optical communication system, apparatus for amplifying an optical signal, said apparatus comprising:~~

a first optical pump energy source disposed to inject optical pump energy into a fiber in a co-propagating direction relative to a transmission direction of said optical signal to cause Raman amplification of said signal; and

~~a second optical pump energy source disposed to inject optical pump energy into~~
said fiber in a counter-propagating direction relative to said transmission direction of said
optical signal to cause Raman amplification of said signal; and

5 wherein said first gain level is greater than 4 dB.

14. The apparatus of claim 13 wherein either said first optical pump energy source
has a power level set to achieve one of a desired gain saturation level or a desired
Rayleigh backscattering level, and said second optical pump energy source has a power
10 level set to obtain a desired gain level given said power level set for said first optical
~~pump energy source.~~

15. ~~The apparatus of claim 13 wherein either 1) given a signal to noise ratio at an~~
output of said fiber, there is a greater four-wave mixing product suppression level
15 achieved than would be achieved using only said second optical pump energy source to
achieve said desired gain level or 2) given a four-wave mixing product level at an output
of said fiber, there is a higher signal to noise ratio than would be achieved using only said
second optical pump energy source to achieve said desired gain level.

20 16. ~~The apparatus of claim 13 further comprising said fiber.~~

17. The apparatus of claim 16 further comprising an Erbium-doped fiber amplifier in
cascade with said fiber.

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18. In an optical communication system, a method for amplifying an optical signal within a fiber by exploiting Raman effects to achieve a desired gain level, said method comprising:

5 injecting co-propagating optical pump energy into said fiber to cause Raman amplification according to a first gain level;

injecting counter-propagating optical pump energy into said fiber to cause Raman amplification according to a second gain level; and

~~wherein said first gain level is greater than 4 dB.~~

19. ~~The method of claim 18 wherein either 1) given a signal to noise ratio at an output~~
of said fiber, there is a greater four-wave mixing product suppression level than would be
achieved injecting only said counter-propagating optical pump energy to obtain said
desired gain level or 2) given a four-wave mixing product level, there is a higher signal to
15 noise ratio than would be achieved using injecting only said counter-propagating optical
energy to obtain said desired gain level.

20. The method of claim 18 wherein injecting co-propagating optical pump energy
comprises injecting co-propagating optical energy at a power level set responsive to a
20 minimum tolerable four-wave mixing product suppression level and a desired signal to
~~noise ratio.~~

21. The method of claim 20 wherein said power level is also set responsive to a
maximum tolerable saturation level.

22. The method of claim 20 further comprising:

further amplifying said signal within an Erbium-doped fiber amplifier.

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~~23. In an optical communication system, apparatus for amplifying an optical signal~~
within a fiber by exploiting Raman effects to achieve a desired gain level, said method
comprising:

means for injecting co-propagating optical pump energy into said fiber to cause

10 Raman amplification;

means for injecting counter-propagating optical pump energy into said fiber to

cause Raman amplification according to a second gain level; and

~~wherein said first gain level is greater than 4 dB~~

24. ~~The apparatus of claim 23 wherein either 1) given a signal to noise ratio at an~~
output of said fiber, there is a greater four-wave mixing product suppression level than
would be achieved injecting only said counter-propagating optical pump energy to obtain
said desired gain level or 2) given a four-wave mixing product level, there is a higher
signal to noise ratio than would be achieved injecting only counter-propagating optical
20 energy to obtain said desired gain level.

25. The apparatus of claim 23 wherein said means for injecting co-propagating

~~optical pump energy comprises means for injecting co-propagating optical energy at a~~

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~~power level set responsive to a minimum tolerable four-wave-mixing product-suppression~~
level and a desired signal to noise ratio.

5 26. The apparatus of claim 23 wherein said power level is also set responsive to a
maximum tolerable saturation level.

27. The apparatus of claim 23 further comprising:

~~means for further amplifying said signal within an Erbium-doped fiber amplifier.~~

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